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Original Article

# COMPARATIVE STUDY OF SAE 1141 CARBON STEEL, T651-7075 ALUMINUM ALLOY & 4340 BILLET STEEL MATERIAL FOR CONNECTING ROD USING ANSYS 16

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***ABSTRACT***

***A connecting rod is a link which derives the rotary motion from the reciprocating motion of piston. Many materials are used for connecting rod. Every material has its own advantages and disadvantages, and are used depending upon the engine requirement, purpose of the engine and other factors that matter. In this paper, a connecting rod with three different materials viz. SAE 1141 Carbon Steel, T651-7075 Aluminum Alloy & 4340 Billet Steel, have been designed using CATIA V5 R20 and analyzed using ANSYS 16. Deformation, equivalent stress and equivalent strain of the connecting rod for all the three materials were compared to the same loads.***

***KEYWORDS: Connecting Rod, CATIA V5 R20, ANSYS 16, SAE1141, Billet STEEL & Aluminum Alloy***

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## 1. INTRODUCTION

The connecting rod is the most important links in a reciprocating I. C Engine. It connects the piston to the crankshaft and is responsible for the conversion of reciprocating motion of piston into rotary motion of the crank which is obtained on the Flywheel [1]. Figure 1 shows a usual form of a Connecting rod. It consists of a long shank, a big end, which is connected to the crank and small end connected to the piston with the help of gudgeon pin. The cross-section of the shank, for high speed engine is generally chosen to be an I or H section and circular for low speed engines. The connecting rod is one of heavy links in the engine. Obtaining reduction in weight and bearing high pressure of the engine for the Connecting rod, and maintaining the cost in an affordable range is a challenge for the engineers. Lighter weights will not only offer lesser inertia force, reduced vibrations and decreased overall engine weight, but will also help economically and ecologically, consuming lesser fuel and reduced emissions from the vehicle.

A lot of engineering materials have been developed for obtaining reduced weight for the same strength and stress bearing ability Aluminum alloys, Steel alloys to mild carbon steels. The most common material for the connecting rod is the Steel. Titanium and Aluminum Alloys are used for reduced weights. Generally, the connecting rod is made through dropped forging, since it is a cost effective process. Connecting rods for automotive applications are typically manufactured by forging from either wrought or powdered forged [2]. Different materials have their advantages and disadvantages. Some are maybe being lighter in weight, but are

costly, while some are cheap and light but cannot withstand the pressure in high speed engines.

The paper deals with the study of comparison of stress and deformation of different materials. The materials selected for this work are SAE 1141 Carbon Steel, T651-7075 Aluminum Alloy and 4340 Billet Steel. The rod was designed on the designing software CATIA V5R20 and analyzed in the analyzing software ANSYS 16. Stress distribution and deformation of these materials for same applied force were observed.

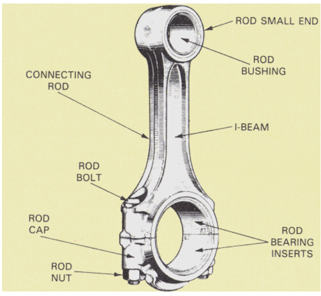



**Figure 1: Connecting Rod [1]**

## 2. MATERIALS

### SAE 1141 CARBON STEEL

The SAE 1141 is a re-sulfurised carbon steel. Resulfurised steel means that after refining of the steel, sulfur has been added again to improve machinabilty. The designation 1141 is followed in SAE and AISI systems [3]. The UNS number is G11410. Table 1 shows the composition & mechanical properties for this steel are as under.

**Table 1: Composition and Mechanical Properties of SAE 1141 Carbon Steel**

| Composition | | Mechanical Properties | |
|---|---|---|---|
| **Elements** | **Contents (%)** | **Properties** | **Units** |
| Iron | 97.73-98.20 | Density | 7.85 g/cc |
| Manganese | 1.35-1.65 | Young's Modulus | 190-210 GPa |
| Carbon | 0.370-0.45 | Poisson's Ratio | 0.27-0.30 |
| Sulfur | 0.08-0.13 | Ultimate Tensile Strength | 675 MPa |
| Phosphorus | 0.04 | Yield Tensile Strength | 360 MPa |
| | | Bulk Modulus | 140 GPa |
| | | Brinell Hardness | 192 |

### T651-7075 ALUMINUM ALLOY

Zinc is the primary alloying element for 7075 Aluminum alloy. It has good fatigue strength and has strength comparable to many steels. Though it has better corrosion resistance than most of the alloys, it has relatively low corrosion resistance than other Aluminum alloys. It is also costlier than other materials used for connecting rod [4]. The composition & mechanical properties of this Aluminum alloy is given below (table 2):

**Table 2: Composition and Mechanical Properties of T651-7075 Al Alloy**

| Composition | | Mechanical Properties | |
|---|---|---|---|
| **Elements** | **% weight** | **Properties** | **Units** |
| Aluminum | 87.1-91.4 | Density | 2.81 g/cc |
| Zinc | 5.1-6.1 | Young's Modulus | 71.7GPa |
| Manganese | 0.3(max) | Poisson's Ratio | 0.33 |
| Chromium | 0.18-0.28 | Ultimate Tensile Strength | 572 MPa |

| Table 2: Contd., | | | |
|---|---|---|---|
| Copper | 1.2-2.0 | Yield Tensile Strength | 503 MPa |
| Titanium | 0.2(max) | Brinell Hardness | 150 |
| Magnesium | 2.1-2.9 | | |
| Silicon | 0.4(max) | | |
| Iron | 0.5 | | |

**4340 BILLET STEEL**

4340 Billet steel contains mainly of Chromium, Nickel and Molybdenum. It has high toughness and strength in the heat treated condition. The 4340 steel has good shock and impact resistance as well as wear and abrasion resistance in the hardened condition [5]. Following (table 3) are its composition and properties:

**Table 3: Composition and Mechanical Properties of 4340 Billet Steel**

| Composition | | Mechanical Properties | |
|---|---|---|---|
| **Elements** | **% weight** | **Properties** | **Units** |
| Chromium | 0.70-0.90 | Density | 7.85 g/cc |
| Nickel | 1.65-2.00 | Young's Modulus | 190-210 GPa |
| Molybdenum | 0.20-0.30 | Poisson's Ratio | 0.27-0.30 |
| Carbon | 0.38-0.34 | Ultimate Tensile Strength | 745 MPa |
| Manganese | 0.65-0.85 | Yield Tensile Strength | 470 MPa |
| Phosphorus | 0.025 | Bulk Modulus | 140 GPa |
| Silicon | 0.15-0.35 | Brinell Hardness | 217 |
| Copper | 0.35 | | |
| Sulfur | 0.025 | | |

## 3. NUMERICAL MODELING OF CONNECTING ROD

The connecting rod has to withstand an enormous amount of force and pressure. The pressure due to gas pressure and inertia of the reciprocating parts are mainly the forces the rod has to bear. The other forces acting on it are: The inertia of the connecting rod, Force due to friction of piston rings, and Force due to friction of piston pin bearing and crankpin bearings. Here we have designed the connecting rod for one particular pressure exerted by gas and analyze the three materials [6].

Following data was considered while designing the crankshaft:

- RPM (N) = 1796
- Maximum gas pressure (p) = 3.15 N/mm$^2$
- Diameter of the piston (D) = 100 mm
- Length of connecting rod = 380 mm
- Stroke = 190 mm

All three connecting rods will be made for this same engine.

Let $F_L$ be the force due to gas pressure on the connecting rod, then;

$F_L$ = Pressure * Area

From the above data, $F_L$ is found to be approximately 25000 N.

The cross-section of the connecting rod is chosen to be I section and the width and height of the section was found. According to Rankine's formula, the ratio of moment of inertia about X-axis $I_{xx}$ to the moment of inertia about Y-axis $I_{yy}$ is equal to or less than 4. By using Rankine's formula, the measurements of the cross section was calculated [7].

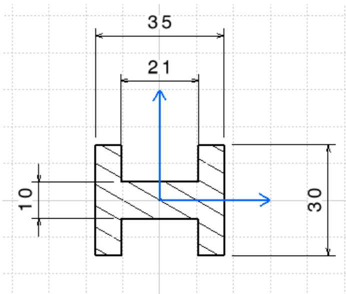



**Figure 2: I-Section**

The dimensions for big end bearing and small end bearing can be calculated as follows:

Let, $d_c$ = diameter of big end bearing

$l_c$ = length of big end bearing = $1.3d_c$

$p_{bc}$ = bearing pressure = $10N/mm^2$

Then, the load on the big end bearing = projected area* bearing pressure

$F_L = d_c * l_c * p_{bc}$

This gives diameter of big end bearing 44mm. Similarly, for small end bearing we get its diameter to be 30mm

Now since we have the dimensions of the connecting rod, we proceed to design the 3Dmodel of the connecting rod in CATIA V5.

## 4. 3D MODEL IN CATIA

The 3D model of the connecting rod will be designed on CATIA V5R20. The profile and 3D model are shown below.

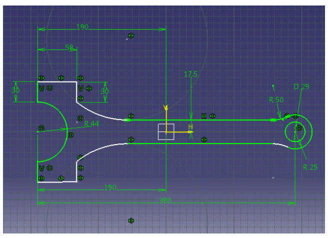


**Figure 3: Connecting Rod Profile**

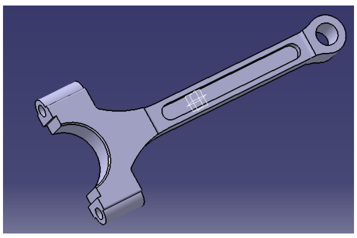
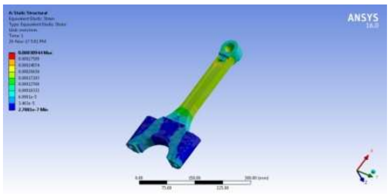


**Figure 4: 3D Model of Connecting Rod**

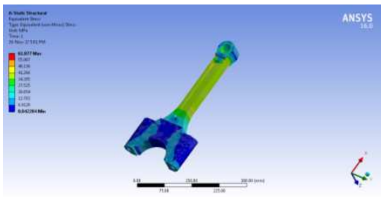
## 5. ANALYSIS IN ANSYS 16

The analysis of the connecting rod was done on the ANSYS 16 software. The materials were being added (imported from CATIA part model) one by one and were analyzed for Equivalent Stress (von Mises stress), Equivalent strain [8] (von Mises strain) and the deformation in each material. The analysis results of the three materials were compared (table 4) to evaluate the best material for the connecting rod.

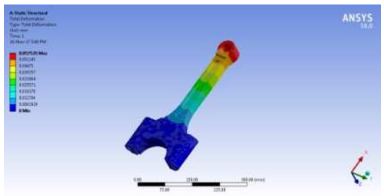
**SAE 1141 Analysis**




**Equivalent Strain**

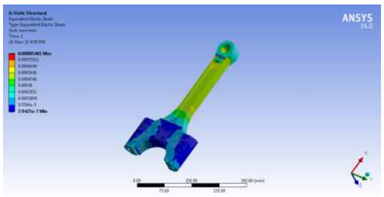



**Equivalent Stress**

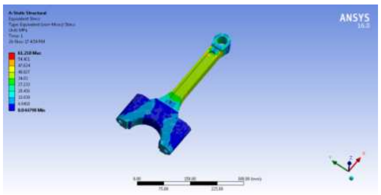



**Deformation**

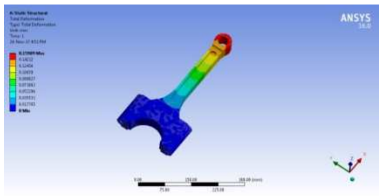
**T651-7075 Aluminum Alloy Analysis**




**Equivalent Strain**

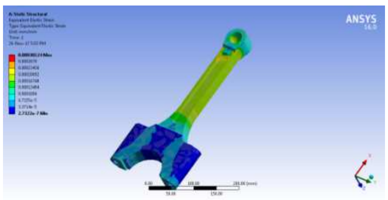



**Equivalent Stress**

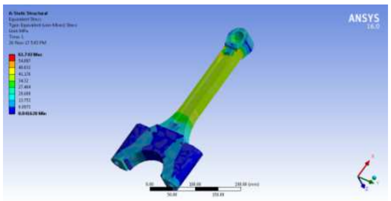



**Deformation**

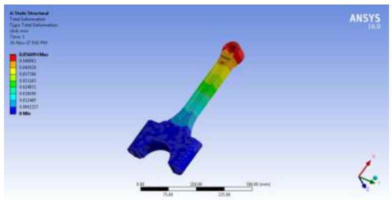
**4340 Billet Steel Analysis**




**Equivalent Strain**




**Equivalent Stress**




**Deformation**

**Table 4: Comparison of SAE1141 T651-7075 Al. Alloy 4340 Billet Steel (Data ANSYS16)**

| | SAE1141 | T651-7075 Al. ALLOY | 4340 BILLET STEEL |
|---|---|---|---|
| Mass (kg) | 6.2 | 2.22 | 6.2 |
| Yield strength (MPa) | 360 | 503 | 710 |
| Equivalent Stress | Min: $4.22 \times 10^{-2}$MPa<br>Max: 61.877 MPa | Min: $4.48 \times 10^{-2}$MPa<br>Max: 61.218 MPa | Min: $4.16 \times 10^{-2}$MPa<br>Max: 61.743 MPa |
| Deformation | $5.753 \times 10^{-2}$ mm | $15.98 \times 10^{-2}$ mm | $5.61 \times 10^{-2}$ mm |
| Equivalent Strain | Min: $2.78 \times 10^{-7}$ MPa<br>Max: $3.09 \times 10^{-4}$ MPa | Min: $7.94 \times 10^{-7}$MPa<br>Max: $8.54 \times 10^{-4}$ MPa | Min: $2.73 \times 10^{-7}$MPa<br>Max:$3.012 \times 10^{-4}$ MPa |

## 6. RESULTS AND DISCUSSIONS

It is evident from the table that weight is almost the same for SAE 1141 and 4340 Billet Steel but the least weight for the same size of the connecting rod was for T651-7075 Aluminum alloy. The yield strength was found to be maximum for 4340 Billet Steel followed by T651-7075 Aluminum alloy and SAE 1141. Equivalent Stress, Deformation and Equivalent Strain however, showed different results, having maximum value for T651-7075 Aluminum alloy.

The aluminum alloy is the lightest among the three and has a higher yield strength than the SAE 1141 carbon steel, though it has the largest deflection among the three. 4340 Billet Steel has the highest yield strength and minimum deformation under the given situation.

## 7. CONCLUSIONS

Our study shows SAE1141 to be a standard material for normal engines comparing all the data available to us. With the advancement in the field of engineering and technology, more and more suitable materials and composites can be introduced which will be economical, light in weight & fulfill the requirement of strength requirement of a Crankshaft. Future work suggests us to compare different available composites and materials used in existing engines for improving the effectiveness, efficiency and make the product cost effective.

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